

Observations of the Moon made at the Radcliffe Observatory, Oxford, during the Year 1892; and a Comparison of the Results with the Tabular Places from Hansen's Lunar Tables.

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The present paper contains the observations of the Right Ascensions and North Polar Distances of the Moon, made at the Radcliffe Observatory during the year 1892. These results are here compared with those deduced from Hansen's Lunar Tables on two suppositions—

- (1) That the mean times found in the usual way, from the sidereal times at mean noon given in the *Nautical Almanac*, were not altered in scale, or affected with any different systematic errors of determination, by the adoption, in 1864, of a different ratio of the Julian year of $365\frac{1}{4}$ "mean solar days" to the mean tropical year.
- (2) That the "mean solar times" which accurately correspond to given "local sidereal times" before and after 1864 are necessarily different from the adoption and use of a "Julian year" and "mean solar day" which are different fractional parts of the mean tropical year, and therefore are different intervals of absolute time.

If these differences are real, and are neglected by astronomers in referring the tabular positions of the Sun, Moon, &c., to the meridians for comparison with the local sidereal times at transit, the effects of the errors made will necessarily be thrown upon the theoretical expressions.

The differences of the errors thus made in practice, according to my views, before and after 1864, are given in Table III.

The periodical errors of Hansen's Tables, after correction, shown by the observations during the year 1892, are not larger than those which will be found to exist during the years 1847 to 1863.

The mean annual errors of Hansen's Tables show small but systematic periodical changes from 1847 to 1863, but since 1864 the errors in longitude have progressively increased until they amount in 1892 to $\pm 19''\cdot 7$. It will be seen that after the corrections, which I have indicated as necessary for a comparison of the changes of the errors of Hansen's Tables before and after 1864, have been applied, the *per saltum* change in 1864 is no longer shown. The mean annual error in longitude, 1847-63, is $-1''\cdot 85$; the mean annual error in longitude, 1864-92, is $-1''\cdot 56$; and the mean annual error in longitude for the whole period, 1847-92, is $-1''\cdot 67$.

For facilities for an accurate comparison between Hansen's Lunar Tables and Observations I am again indebted to the places published in the *Connaissance des Temps*.

Mr. Stone, *Observations of the Moon*

TABLE I.
Radcliffe Observations of the Moon, 1892.
R.A.'s and N.P.D.'s of the Centre of the Moon, 1892; compared with Hansen's Tabular Places, Uncorrected and Corrected for the change in the Unit of Mean Time introduced in the year 1864.

Day, 1892.	Observer.	Limb observed in R.A.	Observed R.A.			N.P.D.	Observed N.P.D.			L.V. I,		
			Hansen minus Observed. Uncorrected.				Hansen minus Observed. Corrected.					
			Correction due to the Change in the Unit of Mean Time.				N.P.D. from Hansen's Tables for Uncorrected Mean Times.					
Jan. 6	41.51	F.B.	I.	0 49 ^s	19 57 ^s	20 53 ^s	+1.36 ^s	-1.46 ^s	-0.10 ^s	S. 88° 30' 23".6	13 35" -9.81 +10.98 +1.17	
7	41.52	W.	I.	1 41	51.40	52.80	+1.40	-1.48	-0.08	S. 82° 3 10' 4	125" -9.69 +10.52 +0.83	
11	41.53	F.B.	I.	5 32	49.34	50.84	+1.50	-1.73	-0.23	N. 64° 12' 47.86	45.31" -2.55 +2.93 +0.38	
13	41.54	R.	I. & II.	7 36	43.36	44.66	+1.30	-1.67	-0.37	N. 64° 5 24.81	26.40" +1.59 -2.64 -1.05	
15	41.55	R.	II.	9 29	56.92	58.07	+1.15	-1.47	-0.32	S. 69° 53' 54.79	60.20" +5.41 -6.71 -1.30	
Feb. 3	41.62	F.B.	I.	1 25	6.62	7.90	+1.28	-1.50	-0.22	S. 83° 47' 26.14	16.19" -9.95 +10.95 +1.00	
8	41.64	R.	I.	6 13	52.97	54.34	+1.37	-1.71	-0.34	N. 63° 17' 14.81	13.80" -1.01 +0.96 -0.05	
11	41.66	F.B.	I.	9 8	54.22	55.61	+1.39	-1.50	-0.11	N. 68° 25' 1.66	6.50" +4.84 -6.13 -1.29	
16	41.68	F.B.	II.	13 2	50.93	52.13	+1.20	-1.23	-0.03	S. 93° 35' 54.13	60.35" +6.22 -9.24 -3.02	
Mar. 7	41.76	W.	I.	6 56	31.01	32.43	+1.42	-1.68	-0.26	N. 63° 4 47.84	47.51" -0.33 -1.01 -1.34	
10	41.77	F.B.	I.	9 43	46.97	48.30	+1.33	-1.42	-0.09	N. 70° 58' 50.23	56.72" +6.49 -7.18 -0.69	
11	41.77	R.	I.	7 55	33.50	34.65	+1.45	-1.61	-0.16	N. 64° 26' 35.47	38.51" +3.04 -3.50 -0.46	
9	41.76	F.B.	I.	8 51	27.19	28.64	+1.45	-1.52	-0.07	N. 67° 10' 1.16	14.47" +3.31 -5.58 -2.27	
10	41.77	F.B.	I.	10 32	46.55	47.55	+1.00	-1.34	-0.34	N. 75° 35' 29.77	37.80" +8.03 -8.31 -0.28	

Correction to be
subtracted from M.T.
for Change of Sidereal
Time at Mean Noon
since 1864.

Nov. 1893.

made at the Radcliffe Observatory etc.

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Hansen minus
Observed.
Corrected.

Correction due to the
Change in the Unit
of Mean Time.

Hansen minus
Observed.
Uncorrected.

N.P.D. from
Hansen's Tables for
Uncorrected Mean
Times.

Observed N.P.D.

Limb observed
in N.P.D.

Hansen minus
Observed.
Corrected.

Correction due to the
Change in the Unit
of Mean Time.

Hansen minus
Observed.
Uncorrected.

R.A. from Hansen's
Tables for Uncor-
rected Mean Times.

Observed R.A.

Limb observed
in R.A.

Observer.

Correction to be
subtracted from M.T.
for Change of Sidereal
Time at Mean Noon
since 1864.

Day, 1892.

s

Mar. 12	4 178	4 178	F.R.	1. 11 19	4.06	5.25	+ 1.19	- 1.27	- 0.08	N.	80° 44' 22.9"	31° 53'	+ 8° 56'	- 9° 03'	- 0° 47'
18	41.80	W.	II.	15 51	17.51	18.96	+ 1.45	- 1.43	+ 0.02	S.	111 17 28.58	35.84	+ 7.26	- 6.22	+ 1.04
20	41.81	R.	II.	17 40	7.32	8.59	+ 1.27	- 1.62	- 0.35	S.	116 31 50.64	53.21	+ 2.57	- 2.31	+ 0.26
Apr. 4	41.87	W.	I.	7 37	9.89	11.23	+ 1.34	- 1.66	- 0.32	N.	63 39 36.14	37.93	+ 1.79	- 1.79	- 1.03
5	41.87	R.	I.	8 34	38.08	39.41	+ 1.33	- 1.56	- 0.23	N.	66 1 36.43	41.47	+ 5.04	- 5.06	- 0.02
6	41.88	F.B.	I.	9 28	7.35	8.51	+ 1.16	- 1.45	- 0.29	N.	69 33 48.60	54.04	+ 5.44	- 6.79	- 1.35
7	41.88	W.	I.	10 17	52.28	53.41	+ 1.13	- 1.36	- 0.23	N.	73 58 2.86	10.28	+ 7.42	- 8.42	- 0.62
8	41.88	R.	I.	11 4	35.92	36.94	+ 1.02	- 1.29	- 0.27	N.	78 58 20.90	29.30	+ 8.40	- 8.86	- 0.46
9	41.89	F.B.	I.	11 49	13.47	14.59	+ 1.12	- 1.24	- 0.12	N.	84 21 2.80	11.44	+ 8.55	- 9.33	- 0.78
11	41.90	W.	I.	13 16	7.75	8.82	+ 1.07	- 1.24	- 0.17	N. & S.	95 26 52.39	61.40	+ 9.01	- 9.30	- 0.29
17	41.92	R.	II.	18 18	21.22	22.29	+ 1.07	- 1.64	- 0.57	N.	117 15 16.68	18.89	+ 2.21	- 0.67	+ 1.54
17	41.92	F.B.	I.	11 49	13.47	14.59	+ 1.12	- 1.24	- 0.12	N.	84 21 2.80	11.44	+ 8.55	- 9.33	- 0.78
18	42.04	R.	II.	21 52	47.03	48.64	+ 1.61	- 1.56	+ 0.05	N.	108 26 56.56	48.12	- 8.44	+ 8.44	+ 0.11
18	42.04	R.	II.	21 52	47.03	48.64	+ 1.61	- 1.56	+ 0.05	N.	86 3 53.54	61.66	+ 8.12	- 9.31	- 1.31
June	1		12 2	45.14	45.99	+ 0.85	- 1.25	- 0.40							

LIV. I,

Hansen minus Observed. Corrected.			Correction due to the Change in the Unit of Mean Time.											
Hansen minus Observed. Uncorrected.			N.P.D. from Hansen's Tables for Uncorrected Mean Times.											
Limb observed in N.P.D.			Observed N.P.D.											
s	h	m	s	s	°	'	''	N.	°	'	''	N.	°	'
June 6 42°12	F.B.	I.	14 14	19°77	21°18	+ 1°41	- 1°30	+ 0°11	10°24	36°10	43°54	+ 7°44	- 8°66	- 1°24
7 42°12	R.	I.	15 1	11°72	12°74	+ 1°02	- 1°37	- 0°35	10°7	13 58°80	66°27	+ 7°47	- 7°70	- 0°23
8 42°13	F.B.	I.	15 51	3°13	4°41	+ 1°28	- 1°46	- 0°18	N.	111 23 41°40	46°29	+ 4°89	- 6°36	- 1°47
9 42°13	W.	I.	16 44	22°11	23°38	+ 1°27	- 1°55	- 0°28	N. & S.	114 37 47°59	53°37	+ 5°78	- 4°54	+ 1°24
12 42°14	R.	II.	19 39	47°51	49°05	+ 1°54	- 1°68	- 0°14	N.	116 16 11°10	10°33	- 0°77	+ 3°01	+ 2°24
13 42°15	F.B.	II.	20 38	46°93	48°84	+ 1°91	- 1°64	+ 0°27	N.	113 43 33°39	31°13	- 2°26	+ 5°55	+ 3°29
14 42°15	W.	II.	21 35	48°52	50°35	+ 1°83	- 1°58	+ 0°25	N.	109 46 49°18	44°13	- 5°05	+ 7°75	+ 2°70
17 42°16	F.B.	II.	0 15	19°88	21°42	+ 1°54	- 1°47	+ 0°07	N.	92 13 69°38	56°91	- 12°47	+ 11°33	- 1°14
30 42°22	W.	I.	11 44	41°85	42°89	+ 1°04	- 1°28	- 0°24	N.	83 58 32°66	40°75	+ 8 09	- 9°58	- 1°49
July 7 42°24	W.	I.	17 18	35°65	36°96	+ 1°31	- 1°62	- 0°31	S. & N.	116 4 8°78	10°73	+ 1°95	- 3°16	- 1°21
Aug. 4 42°36	W.	I.	17 51	37°63	39°01	+ 1°38	- 1°67	- 0°29	S.	117 14 44°81	40°70	- 4°11	+ 1°01	- 3°10
5 42°36	R.	I.	18 51	33°36	34°73	+ 1°37	- 1°72	- 0°35	N.	82 33 51°12	39°20	- 11°92	+ 11°29	- 0°63
12 42°39	W.	II.	1 27	18°37	20°04	+ 1°67	- 1°52	+ 0°15	S.	105 19 40°60	30°99	- 9°61	+ 9°98	+ 0°37
Sept. 5 42°48	W.	I.	22 21	20°77	22°28	+ 1°51	- 1°61	- 0°10	S.	105 19 40°60	30°99	- 9°61	+ 9°98	+ 0°37
7 42°49	W.	II.	0 11	36°69	38°26	+ 1°57	- 1°55	+ 0°02	N.	92 7 45°52	33°55	- 11°97	+ 12°09	+ 0°12
8 42°50	R.	II.	1 6	3°10	4°37	+ 1°27	- 1°56	- 0°29	N.	85 2 66°84	55°74	- 11°19	+ 11°99	+ 0°89
Oct. 1 42°59	W.	I.	20 55	27°01	28°38	+ 1°37	- 1°65	- 0°28	S.	112 48 38°19	32°44	- 5°75	+ 6°65	+ 0°90
3 42°60	R.	I.	22 48	38°41	39°60	+ 1°19	- 1°58	- 0°39	S.	102 26 32°38	21°44	- 10°94	+ 10°79	- 0°15

Nov. 1893. made at the Radcliffe Observatory etc.

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Observers: W., Mr. W. Wickham; R., Mr. W. H. Robinson; F.B., Mr. F. A. Bellamy.

TABLE II.

Radcliffe Observations of the Moon, 1892.

*Errors of the Moon's Tabular Place in Longitude and Ecliptic Polar Distance,
Uncorrected and Corrected for the Change in the Unit of Mean Time
introduced in the year 1864.*

Day, 1892.	Observer.	Limb observed in R.A.	Limb observed in N.P.D.	Errors of Longitude (Hansen minus Observed).		Errors of E.N.P.D. (Hansen minus Observed).	
				Uncor- rected.	Cor- rected.	Uncor- rected.	Cor- rected.
Jan.	F.B.	I.	S.	" + 22.68	- 1.84	" - 1.11	+ 0.50
	W.	I.	S.	" + 22.92	- 1.41	" - 1.56	+ 0.35
	F.B.	I.	N.	" + 20.38	- 3.22	" - 1.59	+ 0.23
	R.	I. & II.	N.	" + 17.60	- 5.11	" - 1.28	- 0.23
	R.	II.	S.	" + 17.16	- 4.71	" - 0.01	+ 0.20
Feb.	F.B.	I.	S.	" + 21.43	- 3.42	" - 2.16	- 0.29
	R.	I.	N.	" + 18.35	- 4.56	" - 1.46	+ 0.06
	F.B.	I.	N.	" + 20.04	- 1.85	" - 1.06	- 0.78
	F.B.	II.	S.	" + 19.10	- 1.58	" - 1.16	- 2.61
Mar.	W.	I.	N.	" + 18.90	- 3.60	" - 2.16	- 1.00
	R.	I.	N.	" + 19.92	- 2.22	" - 0.82	- 0.03
	F.B.	I.	N.	" + 20.27	- 1.56	" - 2.28	- 1.92
	F.B.	I.	N.	" + 20.02	- 1.44	" - 0.13	- 0.23
	R.	I.	N.	" + 16.55	- 4.71	" + 2.08	+ 1.57
	F.B.	I.	N.	" + 19.61	- 1.28	" + 0.95	+ 0.03
	W.	II.	S.	" + 21.35	+ 0.49	" + 2.82	+ 0.96
	R.	II.	S.	" + 17.15	- 4.69	" + 1.97	+ 0.43
Apr.	W.	I.	N.	" + 18.09	- 4.42	" - 1.22	- 0.30
	R.	I.	N.	" + 18.99	- 3.07	" + 0.35	+ 0.77
	F.B.	I.	N.	" + 17.27	- 4.31	" + 0.02	0.00
	W.	I.	N.	" + 17.95	- 3.33	" + 1.05	+ 0.62
	R.	I.	N.	" + 17.17	- 3.86	" + 1.93	+ 1.11
	F.B.	I.	N.	" + 18.83	- 1.96	" + 1.17	0.00
	W.	I.	N. & S.	" + 18.24	- 2.47	" + 2.32	+ 0.69
	R.	II.	N.	" + 14.23	- 7.66	" + 2.64	+ 1.31
May	R.	I.	N.	" + 16.16	- 4.77	" + 3.18	+ 2.11
	W.	I.	N.	" + 16.21	- 4.49	" + 2.11	+ 0.31
	R.	I.	N.	" + 17.01	- 3.70	" + 2.78	+ 0.86
	F.B.	II.	S.	" + 20.31	- 0.93	" + 4.41	+ 2.55
	R.	II.	S.	" + 15.79	- 6.02	" + 2.16	+ 0.70
	R.	II.	N.	" + 24.56	+ 0.71	" - 0.16	+ 0.14

Nov. 1893. made at the Radcliffe Observatory etc.

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Day, 1892.	Observer.	Limb observed in R.A.	Limb observed in N.P.D.	Errors of Longitude (Hansen minus Observed).		Errors of E.N.P.D (Hansen minus Observed).	
				Uncor- rected.	Cor- rected.	Uncor- rected.	Cor- rected.
June 3	R.	I.	N.	+ 14.95	- 6.06	+ 2.37	+ 1.11
6	F.B.	I.	N.	+ 21.96	+ 1.11	+ 0.17	- 1.69
7	R.	I.	N.	+ 16.13	- 4.88	+ 3.09	+ 1.18
8	F.B.	I.	N.	+ 18.50	- 2.77	+ 1.02	- 0.91
9	W.	I.	N. & S.	+ 17.95	- 3.63	+ 3.51	+ 1.72
12	R.	II.	N.	+ 20.63	- 2.24	+ 2.74	+ 1.89
13	F.B.	II.	N.	+ 26.06	+ 2.76	+ 4.50	+ 4.13
14	W.	II.	N.	+ 26.18	+ 2.48	+ 3.58	+ 3.70
17	F.B.	II.	N.	+ 26.24	+ 1.42	- 2.28	- 0.63
June 30	W.	I.	N.	+ 17.51	- 3.89	+ 1.25	+ 0.06
July 7	W.	I.	S. & N.	+ 17.78	- 4.26	+ 0.66	- 0.90
Aug. 4	W.	I.	S.	+ 18.46	- 3.92	- 1.33	- 2.72
5	R.	I.	S.	+ 18.62	- 4.38	- 2.45	- 3.51
12	W.	II.	N.	+ 27.52	+ 2.31	- 1.89	+ 0.24
Sept. 5	W.	I.	S.	+ 23.92	- 1.49	- 1.01	- 0.18
7	W.	II.	N.	+ 26.43	+ 0.23	- 1.63	+ 0.23
8	R.	II.	N.	+ 21.80	- 4.35	- 3.02	- 0.83
Oct. 1	W.	I.	S.	+ 19.88	- 3.99	- 0.28	- 0.21
3	R.	I.	S.	+ 20.34	- 5.24	- 3.49	- 2.31
5	R.	I.	S.	+ 22.15	- 4.60	- 3.23	- 1.08
10	R.	II.	N.	+ 22.85	- 2.14	- 1.43	+ 0.12
Nov. 1	R.	I.	S.	+ 17.87	- 8.24	- 2.62	- 0.66
3	R.	I.	S.	+ 20.34	- 6.69	- 4.69	- 2.23
5	R.	II.	N.	+ 20.69	- 6.14	- 1.76	+ 0.53
Nov. 29	R.	I.	S.	+ 18.32	- 7.25	- 3.44	- 1.40
30	R.	I.	S.	+ 19.03	- 7.07	- 3.38	- 1.07
Dec. 3	W.	I. & II.	N.	+ 22.60	- 4.25	- 3.13	- 1.06
12	R.	II.	S.	+ 15.49	- 5.67	- 0.52	- 2.35
Dec. 24	R.	I.	S.	+ 18.43	- 5.33	- 3.41	- 2.42
26	W.	I.	S.	+ 18.92	- 5.80	- 2.82	- 0.98
29	R.	I.	S.	+ 19.41	- 6.66	- 4.36	- 2.10
30	W.	I.	S.	+ 19.17	- 7.18	- 2.83	- 0.73
Mean of Errors, without regard to sign ...				19" 687	3" 775	2" 032	1" 076
Mean Errors for Year				+ 19" 687	- 3" 410

TABLE III.

Mean Excess over Observation of the Moon's Tabular Place in Longitude for the years 1847 to 1892, as computed from Hansen's Tables.

Uncorrected and Corrected for the change in the Unit of Mean Time introduced in the year 1864.

Year.	Errors of Longitude (Hansen minus Observed).	
	Uncorrected.	Corrected.
1847	+ 0°51'	+ 0°51'
1848	- 0°53	- 0°53
1849	- 1°08	- 1°08
1850	- 0°97	- 0°97
1851	- 1°93	- 1°93
1852	- 1°57	- 1°57
1853	- 2°18	- 2°18
1854	- 2°34	- 2°34
1855	- 1°40	- 1°40
1856	- 1°51	- 1°51
1857	- 2°41	- 2°41
1858	- 2°61	- 2°61
1859	- 2°49	- 2°49
1860	- 3°62	- 3°62
1861	- 2°95	- 2°95
1862	- 2°83	- 2°83
1863	- 1°61	- 1°61
1864	+ 0°12	- 0°81
1865	+ 1°27	- 0°22
1866	+ 2°14	- 0°22
1867	+ 3°48	+ 0°36
1868	+ 4°12	+ 0°28
1869	+ 4°28	- 0°35
1870	+ 4°83	- 0°66
1871	+ 6°96	+ 0°44
1872	+ 7°31	+ 0°10
1873	+ 8°24	+ 0°20
1874	+ 9°29	+ 0°56
1875	+ 9°87	+ 0°36
1876	+ 9°80	- 0°50
1877	+ 9°23	- 1°90
1878	+ 8°22	- 3°60
1879	+ 9°63	- 3°12
1880	+ 10°89	- 2°77
1881	+ 10°51	- 4°06
1882	+ 12°68	- 2°51
1883	+ 14°71	- 1°50
1884	+ 14°65	- 1°91
1885	+ 15°20	- 1°82
1886	+ 15°34	- 2°53
1887	+ 15°70	- 3°25
1888	+ 17°68	- 2°46
1889	+ 17°37	- 3°51
1890	+ 18°02	- 3°55
1891	+ 19°30	- 2°90
1892	+ 19°69	- 3°41

Mean Annual Error
in Longitude
from 1847 to 1863
= - 1°.85.

Mean Annual Error
in Longitude
from 1864 to 1892
(taken out with the
corrected argument)
= - 1°.56.

1847 to 1879: Greenwich observations. 1880 to 1882: Mean of Greenwich and Radcliffe. 1883 to 1892: Radcliffe observations.

Radcliffe Observatory, Oxford:
1893 November 9.

Preliminary Note on the Reduction of Measures of Photographic Plates. By H. H. Turner, M.A., B.Sc.

1. The following is an attempt to simplify the processes already suggested for the reduction of measures of stellar photographs, and especially measures of the plates of the Astrographic Chart.

2. The fundamental property of a photographic plate is that it is a projection of the celestial sphere from a point (the centre of the object-glass) on a plane (the photographic plate itself). This statement must be qualified just so far as the image of the star is displaced by—

- (a) Distortion of the objective;
- (b) Displacements of the photographic film;
- (c) Refraction and aberration.

3. Neglecting for the moment these disturbing causes, it follows that any great circle on the sphere projects into a straight line on the plate; and any straight line on the plate corresponds to a great circle on the sphere, and hence to a straight line on any other plate containing the same region.

4. The appropriateness of using rectilinear co-ordinates is thus suggested: for the transformation from any rectilinear co-ordinates on one plate to any rectilinear on another takes a simple form. Let (x, y) , (ξ, η) be any rectilinear co-ordinates of the same point on the two plates; then the following general relations hold:

$$\xi = \frac{Ax + By + C}{Kx + Ly + M}, \quad \eta = \frac{Dx + Ey + F}{Kx + Ly + M}.$$

It is readily seen that the denominator must be the same in the two cases, for the equation

$$\lambda\xi + \mu\eta + \nu = 0$$

represents a straight line on one plate for all values of λ, μ, ν , and hence must represent a straight line on the other. The above formulæ give the equation to this straight line, viz.

$$\lambda(Ax + By + C) + \mu(Dx + Ey + F) + \nu(Kx + Ly + M) = 0.$$

5. The above formulæ are quite general, but a more convenient form may be given to them in the case of co-ordinates measured approximately in similar directions on the two plates, as will generally be the case for the plates of the Astrographic Chart. We shall then have *approximately*

$$\xi = x + \text{const.}, \quad \eta = y + \text{const.},$$